Satellite Anomaly Assessment

U.S. AIR FORCE

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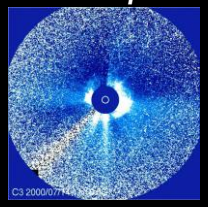
Major Space Environment Hazards

False stars in star tracker CCDs

Before

During exposure to multi-MeV protons



Before *After*

Surface degradation from radiation

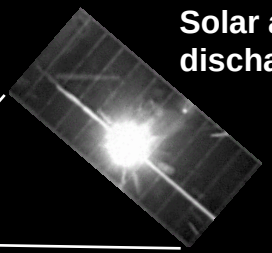
Solar array power decrease due to radiation damage

Single event effects in microelectronics

1101 ⇒ 0101

Electronics degrade due to total radiation dose

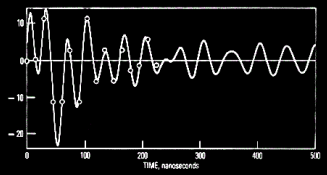
Solar array arc discharge



Spacecraft components become radioactive

Electromagnetic pulse from vehicle discharge (on surface, behind thin shielding, or deep inside)

Induced Voltage



Time

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Locations of Operational Space Environment Hazards

Single Event Effects (SEEs)

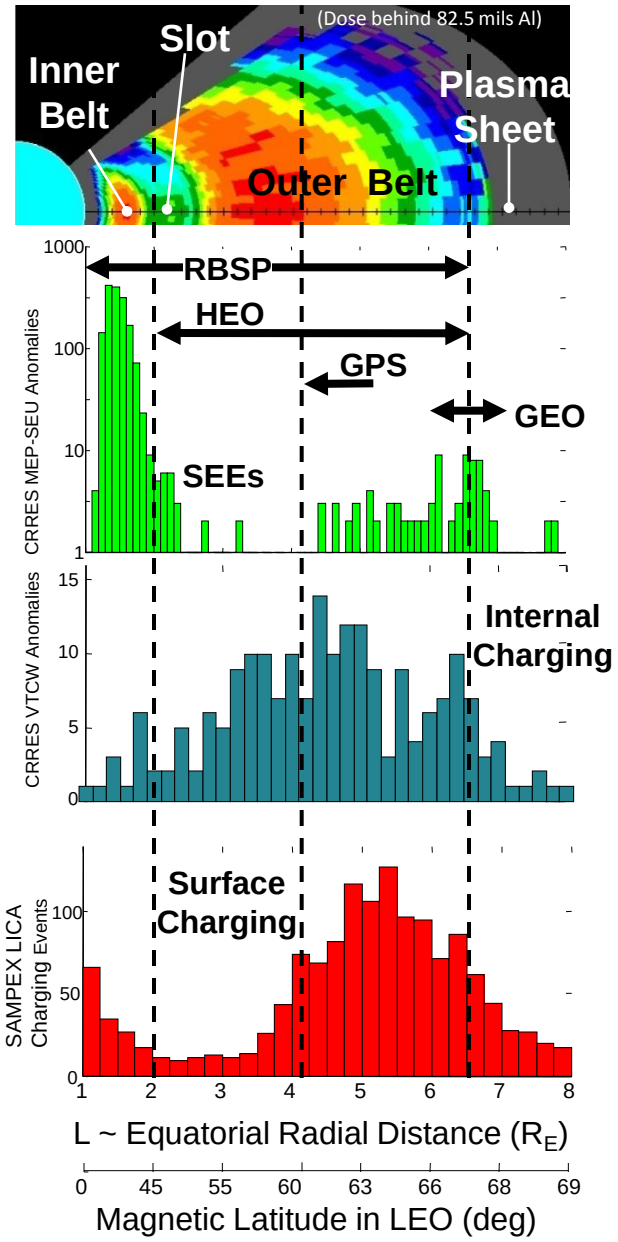
- inner (proton) belt and higher L shells with solar particle event
- quiet-times from galactic cosmic rays

Internal charging and resulting **electrostatic discharges (ESD)**

- broad range of L values
- corresponding to the outer belt
- where penetrating electron fluxes are high

Surface charging and resulting **ESD**

- spacecraft or surface potential elevated
- 2000-0800 local time in the plasma sheet
- regions of intense field-aligned currents
- observed, but not explained, at very low L



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Space is Not One Place: January 2012 SEP Events

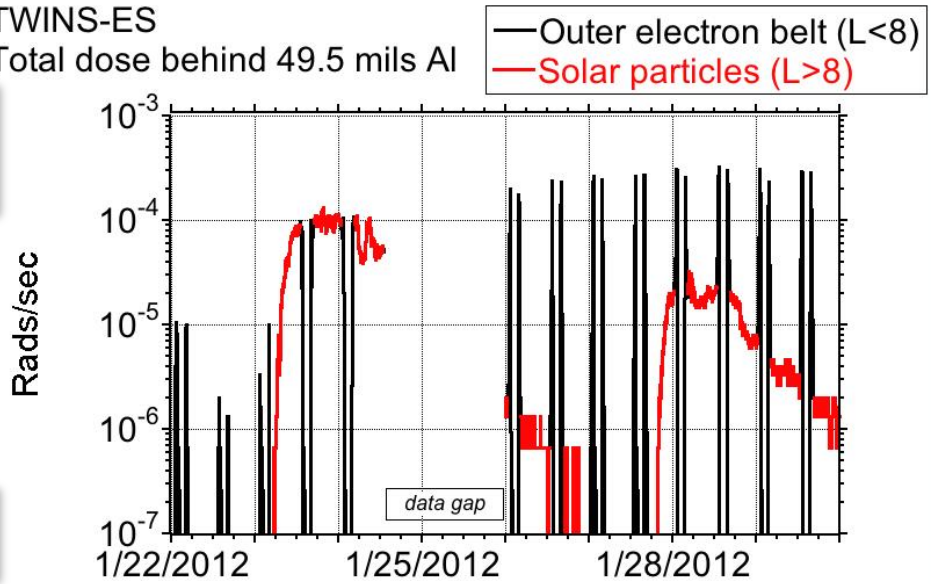
For orbits such as HEO, **solar energetic particles** are important sources of heavy ions that can cause single event effects

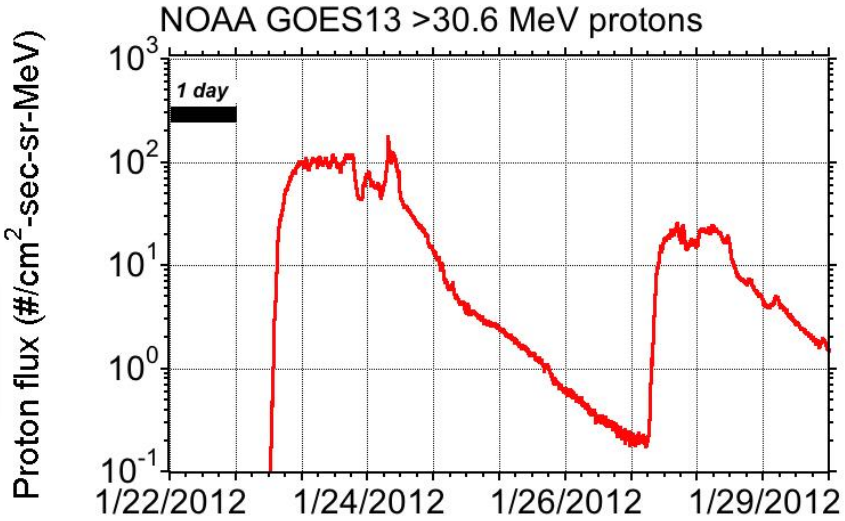
HEO

However, the trapped electrons and protons in the **Van Allen belts** dominate the total dose hazard

GEO

For awareness in HEO, the timing of the GEO environment is good information but not sufficient for anomaly diagnosis





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Anomalies Attributed to the Space Environment

Two anomaly studies attributed to space environment:

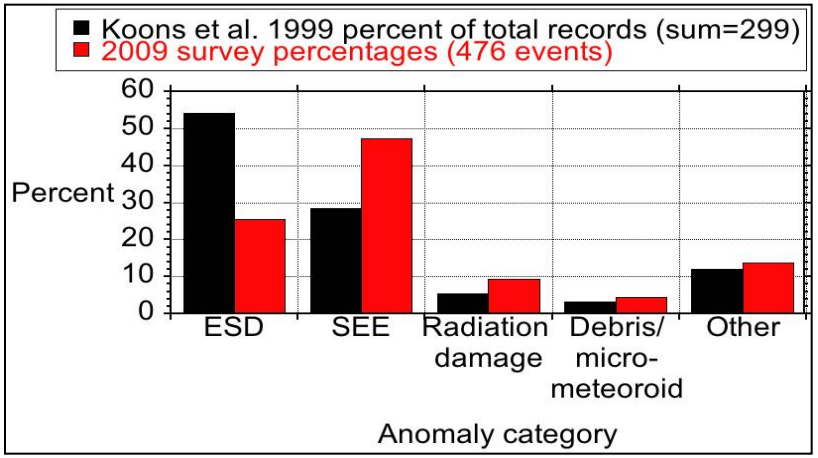
- Koons et al. Aerospace Report No.TR-99(1670)-1
- Unpublished (2009)

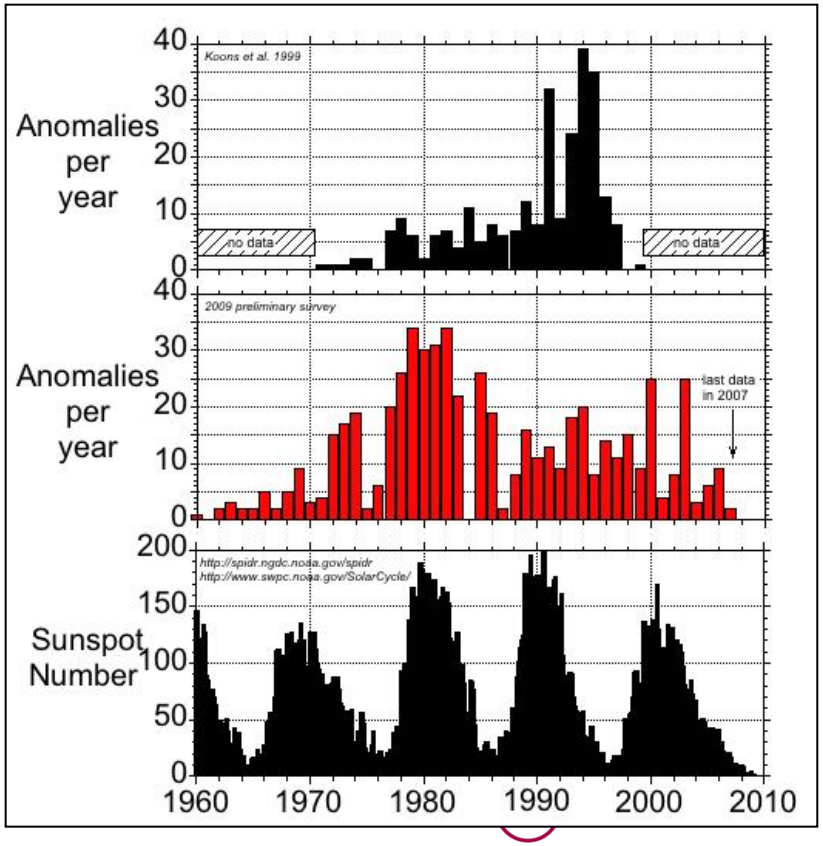
Databases differ

- coverage in time/space vehicles
- most frequent attributions (SEE or ESD)

However, two conclusions clear:

- Anomalies occur at all times
- Vehicle charging and single-event effects are the most frequently cited causes

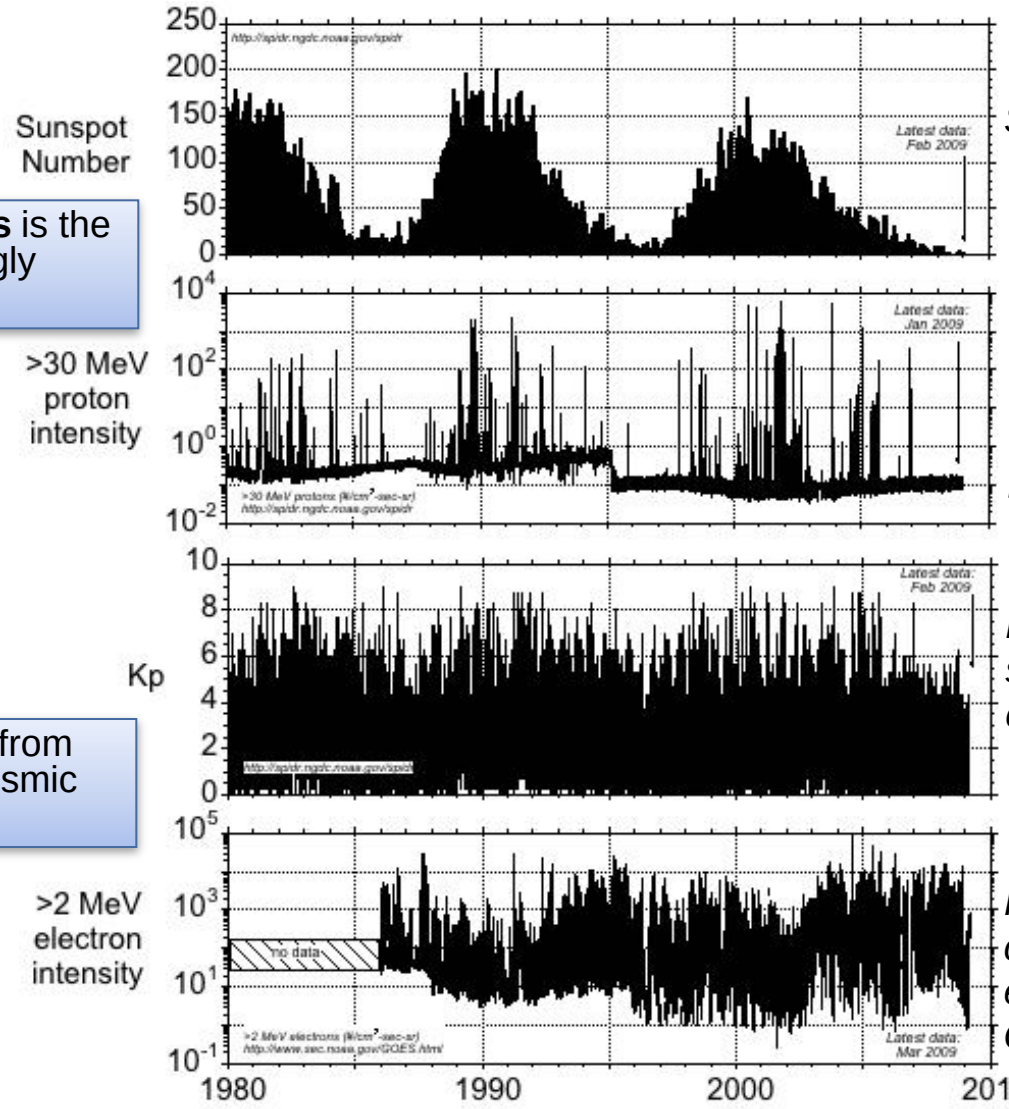




Environment Hazards Versus Solar Cycle

SEE from solar energetic particles is the only hazard whose probability strongly depends on **solar cycle**

Vehicle charging (and single events from the inner van Allen belt & galactic cosmic rays) can occur at any time



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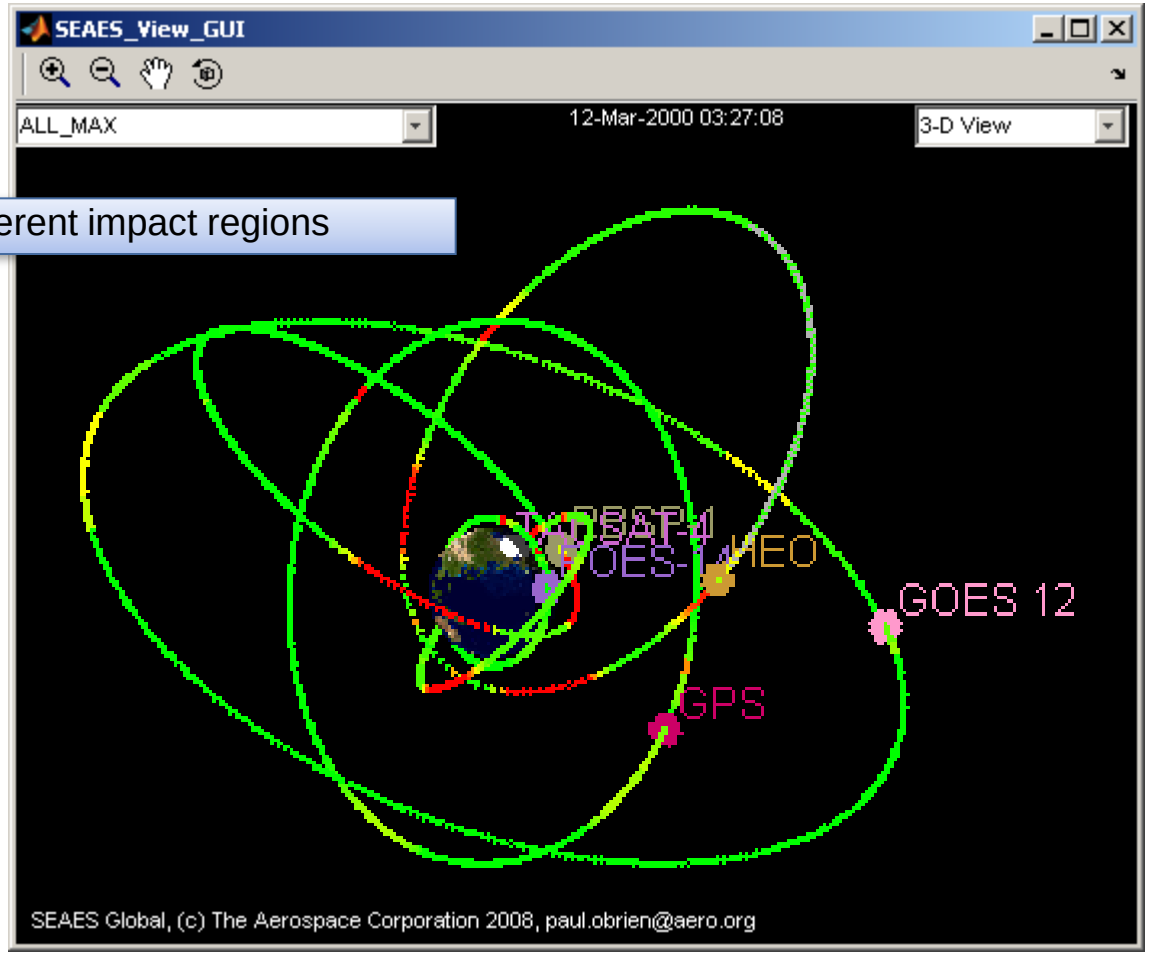
Hazard Visualization

Very different impact regions



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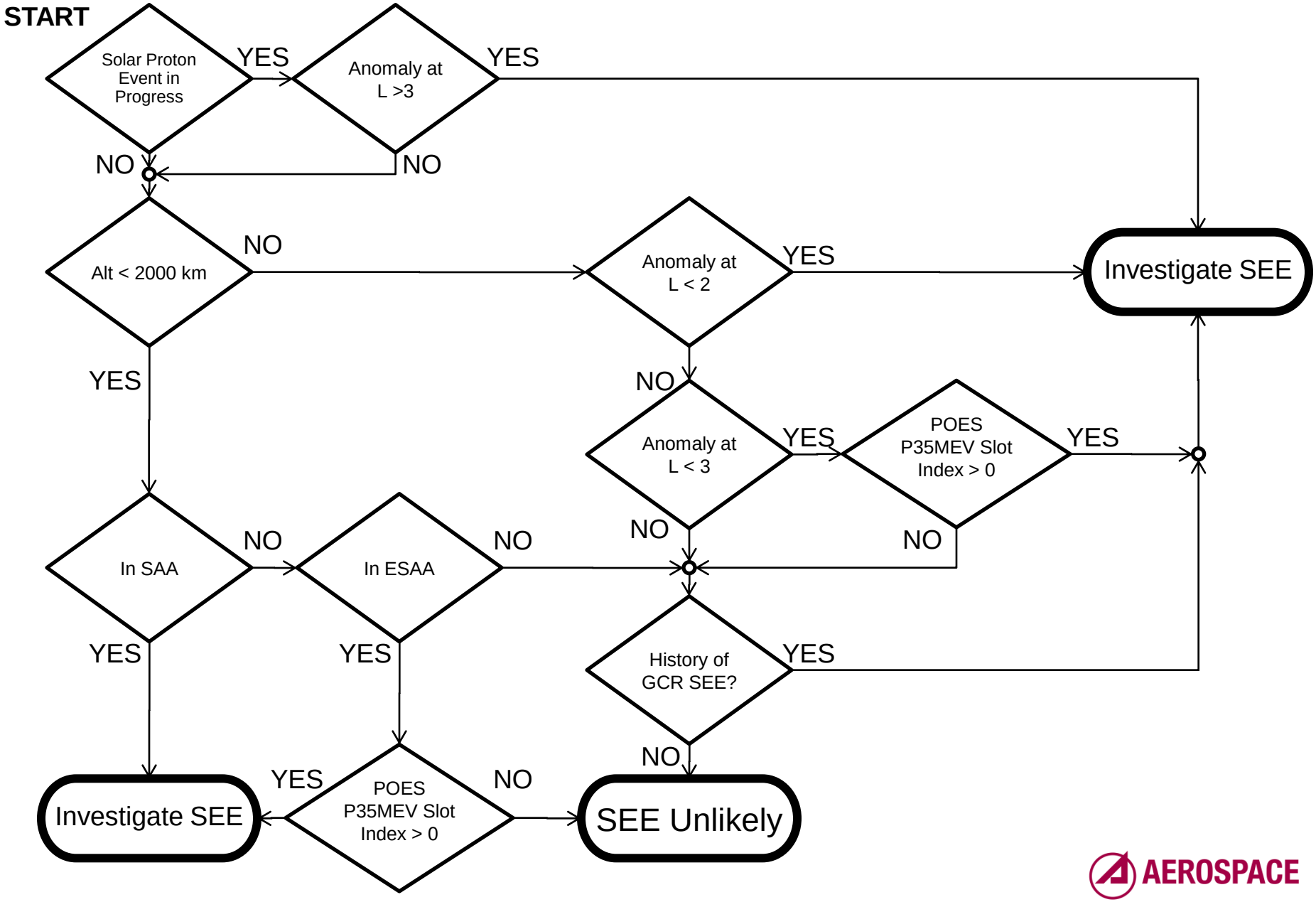
Single Event Effects Flow Chart



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Initial Global Specification Targets

Surface Charging:

- Kp, AE
- Field-Aligned Current intensity (LEO)
- Electron temperature

SEE:

- 20-50 MeV proton flux
- (heavy ions would be nice, too)

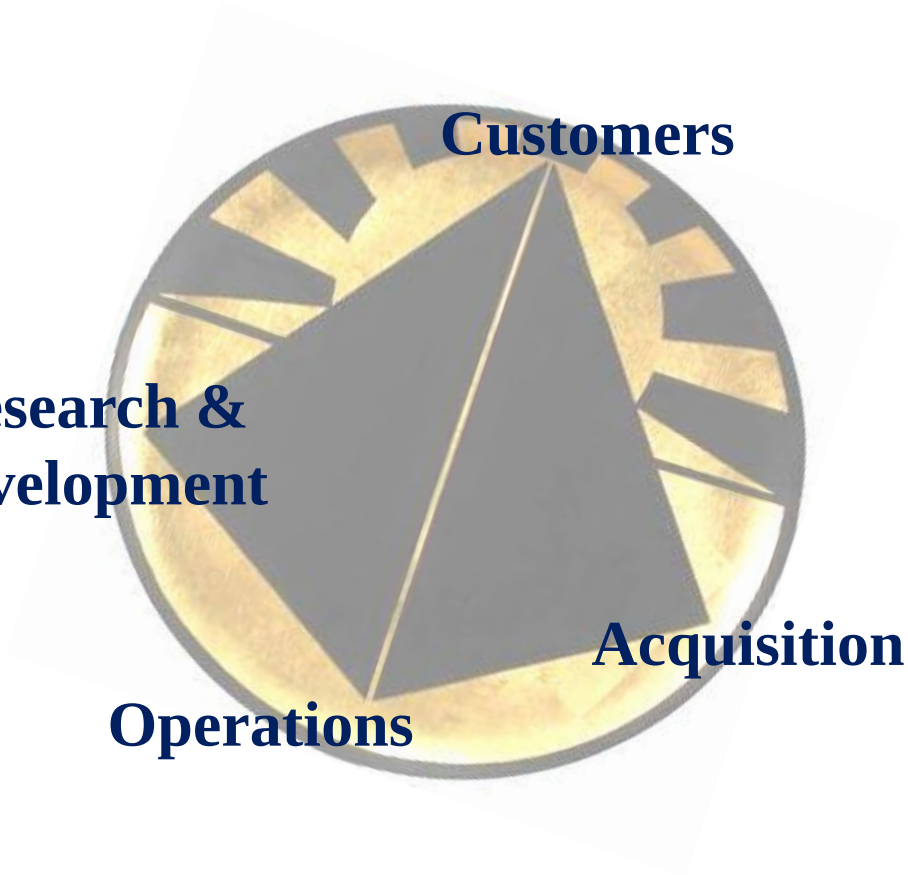
Internal Charging:

- 0.3-2 MeV electron flux

Total Dose:

- 1-20 MeV proton flux

Questions?



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Rising Sun Over Pyramid (painting) – Paul Greco, 2009